CONFIDENTIAL

Copy No. 282

RM No. L7C05

NACA

RESEARCH MEMORANDUM

DRAG CHARACTERISTICS OF RECTANGULAR AND SWEPT-BACK NACA 65-009 AIRFOILS HAVING VARIOUS ASPECT RATIOS AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

By

Warren A. Tucker and Robert L. Nelson

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

April 22, 1947

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

DRAG CHARACTERISTICS OF RECTANGULAR AND SWEPT-BACK NACA 65-009 AIRFOILS HAVING VARIOUS ASPECT RATIOS AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

By Warren A. Tucker and Robert L. Nelson

SUMMARY

Tests have been made at the Pilotless Aircraft Research Test Station at Wallops Island, Va., to determine the effect of sweepback angle and aspect ratio on the drag at supersonic speeds of wings of NACA 65-009 airfoil section. A previous paper has presented the results obtained for wings having aspect ratios of 1.5 and 2.7 and sweepback angles of 0°, 34°, 45°, and 52°. The present paper extends these results to include aspect ratios of 3.8 and 5.0.

For the range of Mach numbers investigated (M = 1.0 to 1.3), it was found that the drag coefficient decreased as the sweepback angle increased, the rate of decrease being somewhat greater for the larger aspect ratios.

In general, for Mach numbers greater than a value somewhat less than that at which the Mach line lies along the leading edge, the drag coefficient decreased with a decrease in aspect ratio. This effect of aspect ratio was more in evidence at the lower angles of sweep; at a sweepback angle of 45° the change in drag coefficient was very small between aspect ratios of 1.5 and 5.0.

The results are compared with theoretical calculations and with other experimental data.

INTRODUCTION

To obtain information on the drag of wings at supersonic speeds a series of tests is being conducted at the Pilotless Aircraft Research Test Station at Wallops Island, Va., of a series of identical rocket-propelled bodies carrying wings of various sweepback angles and aspect ratios. By subtracting the drag of a wingless body from the drag of an identical body carrying a wing, a measure of the wing drag is obtained.

The first report of this investigation (reference 1) presented the results of drag measurements made in this manner on rectangular and swept-back wings of NACA 65-009 airfoil section for aspect ratios of 1.5 and 2.7. Since the publication of reference 1, data have been obtained for three additional wings having aspect ratios up to 5.0. The present paper gives these results.

MODELS AND TESTS

In the present investigation, data were obtained for three wings: two of aspect ratio 3.8 with sweepback angles of 0° and 34°, and one of aspect ratio 5.0 with a sweepback angle of 45°. A drawing of the general model arrangement is shown in figure 1, and photographs of the models are given in figures 2, 3, and 4. The wings were mounted on identical rocket-propelled bodies at zero incidence with the midsemispan quarter-chord point at the center of gravity of the fully loaded model. The wings had no twist, taper, or dihedral. The NACA 65-009 airfoil sections were normal to the leading edge. The test bodies were of all wooden construction and were 5 inches in diameter and approximately 5 feet long. The bodies were made hollow to accomodate the propulsion unit, a standard 3.25-inch Mk. 7 aircraft rocket motor developing about 2200 pounds of thrust for 0.87 second at an ambient preignition temperature of 69° F. The stabilizing fins were rotated 45° out of the plane of the wings to minimize the effect of the wing wake on the tail. Data were obtained for one model of each configuration except the configuration which carried the wing of aspect ratio 3.8 swept back 34°. For this configuration, data were obtained for two identical models.

The experimental data were obtained by launching the model at an angle of 75° to the horizontal and determining its velocity along the flight path by the use of continuous-wave Doppler Radar (AN/TPS-5). A description of the radar method is given in reference 2. A typical curve of velocity against flight time obtained from a radar record is given in figure 6. The drag data were obtained by differentiating that portion of the curve during which the models were coasting (after the propellant had been expended). Drag values, converted to standard sea-level density, are presented in figure 7 against flight velocity for two identical test bodies having wings of 34° sweepback and 3.8 aspect ratio. The values of total drag were converted to corresponding values of total drag coefficient based on the exposed wing plan-form area, which was 200 square inches for all models. The aspect ratios were based on the total span and area, which included the shaded portion shown blanketed by the body in figure 1. The values of temperature and static pressure used in calculating the drag coefficients and Mach numbers were obtained from radiosonde observations made at the time of firing. The tests covered a Mach number range from about 1.00 to about 1.35.

RESULTS AND DISCUSSION

The results of the investigation, together with comparable results of reference 1, are given in figure 8 as curves of total drag coefficient and wing drag coefficient against Mach number. The curves of wing drag coefficient were derived by taking the difference between the total drag coefficient curves of the winged configurations and that of the sharp-nosed wingless body of reference 3 (this body, which is shown in fig. 5, is identical to the bodies used in the present investigation). The wing drag coefficients thus include any possible effects of interference between wing and fuselage.

The greatest inaccuracies in the present data occur below Mach numbers of about 1.0. First, the slope of the velocity-time curve is sufficiently smaller in this region to incur a larger percentage error in computing accelerations. Second, the rate of change of drag with Mach number in the range below $M = 1.0$ is such that a small error in Mach number in this region can cause a considerable error in the curve. A study of the available drag data for which radar records were obtained for two identical models at $M < 1$ indicates that not a great deal of reliance should be placed on the drag data of the present paper at Mach numbers below 1.0. It is common to have differences in drag coefficient of ±10 percent in this region. In the higher Mach number range, the accuracy is within ±3 percent. There is promise of obtaining more accurate low Mach number data from future tests through refinements in instrumentation.

The accuracy in velocity measurement has been estimated to be well within ±1 percent, the largest error in this measurement being that which arises from the very small curvature of the flight path. The temperature and pressure measurements obtained by the use of radiosonde observations hold the accuracy of Mach number to ±1 percent.

The data of the present paper to a certain extent agree with the calculations of reference 4. For example, it is pointed out in reference 4 that for Mach numbers approaching that at which the Mach line lies along the leading edge, a wing of low aspect ratio should have a lower wave drag than one of high aspect ratio, and that for a Mach number considerably below this value the effect of aspect ratio should reverse. This means that for a sweepback angle of 34° and a Mach number of about 1.2, the drag coefficient would be expected to decrease with decreasing aspect ratio, and that for some Mach number appreciably less than 1.2 the effect of aspect ratio on drag coefficient should reverse. The data of figure 8 for 34° sweepback tend to follow this theoretically calculated behavior, a partial reversal occurring at a Mach number of about 1.05 (the data are not entirely consistent with regard to reversal). The curves for the wings of 45° sweepback lie too close to one another to permit making any definite statements.

The data of figure 8 (cross-plotted in fig. 9, which also presents data from other sources to be discussed later) show that the decrease in drag coefficient with increasing sweepback noted in reference 1 for aspect ratios of 1.5 and 2.7 also holds for an aspect ratio of 3.8. The decrease in drag coefficient for a given increase in sweepback angle seems to be somewhat greater for the higher aspect ratios. The data also indicate, as did those of reference 1, that the effect of decreasing the aspect ratio at constant sweepback is generally to decrease the drag coefficient, and that the magnitude of this effect at a given Mach number diminishes with increasing sweepback angle (at a sweepback angle of 45°, only negligible changes in drag coefficient result when the aspect ratio is changed from 5.0 to 1.5).

In figure 9, a comparison is made of the experimental results presented herein, and the theoretical calculations of the wave drag for an isolated 9-percent thick biconvex parabolic-arc airfoil based on the results of reference 4 for 34° and 45° sweepback. Also included are heretofore unpublished theoretical results by the senior author of reference 4 for a wing of 0° sweep, based on the linearized theory used in reference 4. The comparison between the theoretical and experimental drag coefficients of the unswept wings is not particularly valid since the theoretical requirement that the bow wave be attached to the airfoil is not fulfilled by the NACA 65-009 airfoil. However, the comparison is made for completeness. A comparison is also made with some results obtained by the freely-falling-body technique (reference 5). The agreement between theoretical and experimental values is fairly good considering that the theory did not take into account boundary-layer effects and interference effects. In addition, the theoretical results are for a sharp-nosed parabolic-arc profile. The lack of close agreement between the results of this paper and the results of reference 5 is probably due in part to the difference in interference measured by the two methods of testing.

CONCLUDING REMARKS

Flight tests to determine the effect of aspect ratio and sweepback on the drag of wings of NACA 65-009 airfoil section were made at the Pilotless Aircraft Research Test Station at Wallops Island, Va. For the range of Mach numbers, aspect ratios, and sweepback angles investigated, the following statements can be made:

The drag coefficient decreased as the angle of sweepback increased. The rate of decrease was slightly greater for the higher aspect ratios. In general, for Mach numbers greater than the value at which the Mach line lies a little ahead of the leading edge, the drag coefficient decreased with a decrease in aspect ratio. This effect of aspect ratio diminished as the sweepback angle was increased, until at an angle of 45° there were only negligible changes in drag coefficient for aspect ratios between 1.5 and 5.0.

These results substantiate the findings of a previous similar investigation, and extend the findings to higher aspect ratios.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Alexander, Sidney R., and Katz, Ellis: Drag Characteristics of Rectangular and Swept-Back NACA 65-009 Airfoils Having Aspect Ratios of 1.5 and 2.7 as Determined by Flight Tests at Supersonic Speeds. NACA RM No. L6J16, 1946.

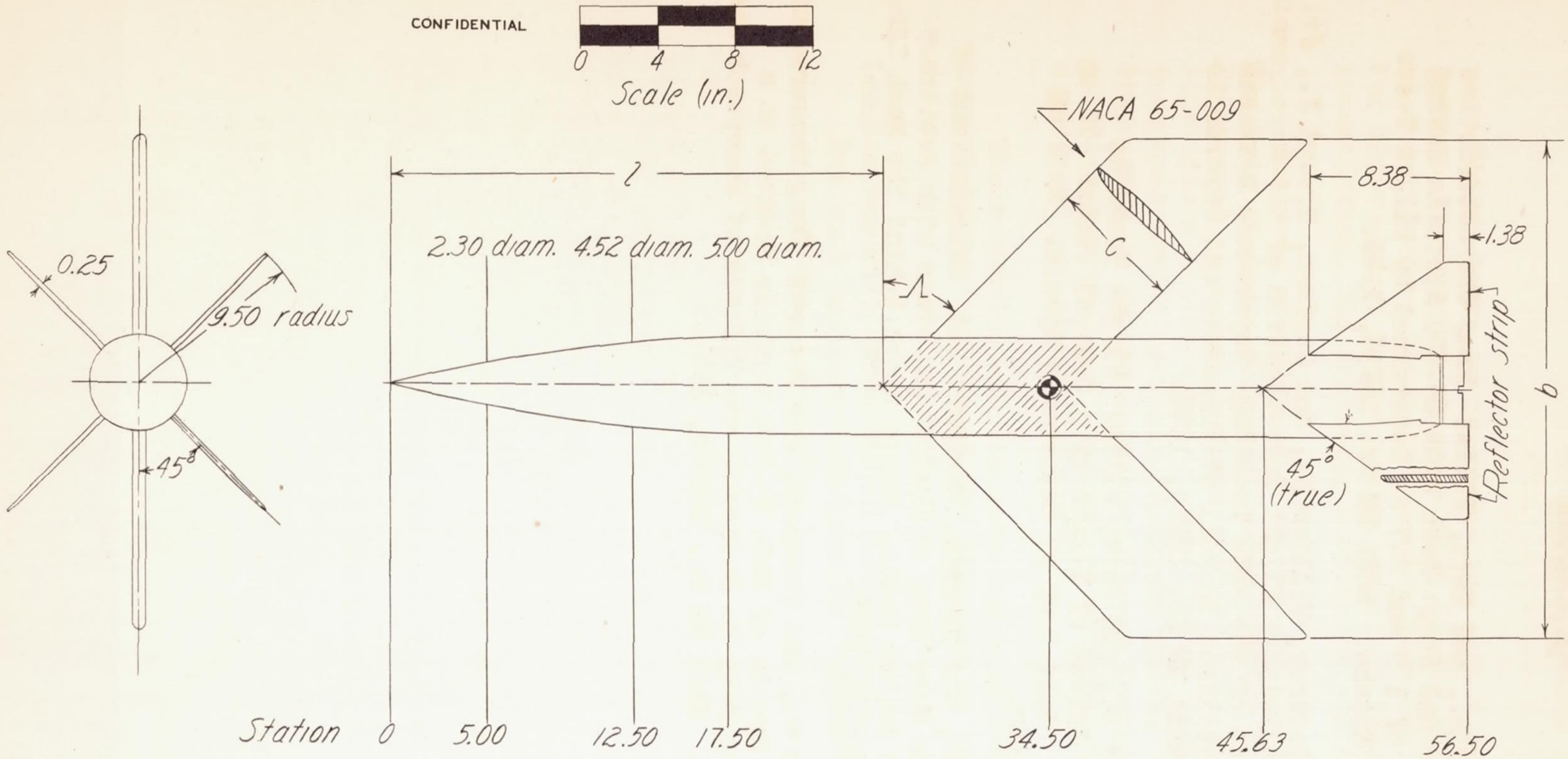
2. Pitkin, Marvin, Gardner, William N., and Curfman, Howard J., Jr.: Results of Preliminary Flight Investigation of the Aerodynamic Characteristics of the NACA Two-Stage Supersonic Research Model RM-1 Stabilized in Roll at Transonic and Supersonic Velocities. NACA RM No. L6J23, 1946.

3. Alexander, Sidney R., and Katz, Ellis: Flight Tests to Determine the Effect of Length of a Conical Windshield on the Drag of a Bluff Body at Supersonic Speeds. NACA RM No. L6J16a, 1947.

4. Harmon, Sidney M., and Swanson, Margaret D.: Calculations of the Supersonic Wave Drag of Nonlifting Wings with Arbitrary Sweepback and Aspect Ratio. Wings Swept behind the Mach Lines. NACA RM No. L6K29, 1946.

5. Mathews, Charles W., and Thompson, Jim Rogers: Drag Measurements at Transonic Speeds of NACA 65-009 Airfoils Mounted on a Freely Falling Body to Determine the Effects of Sweepback and Aspect Ratio. NACA RM No. L6K08c, 1947.

CONFIDENTIAL



Λ deg.	A	b in.	c in.	l in.
0			13.33	31.28
34	1.5	20.00	11.05	28.02
45			9.43	26.46
0			9.65	32.09
34	2.7	25.73	8.00	27.74
45			6.88	25.76
0	3.8	30.18	7.94	32.49
34			6.58	28.96
45	5.0	30.72	4.84	26.43

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

Figure 1.- General arrangement of test body indicating aspect ratios and sweepback angles investigated. Wing area (exposed), 200 sq in.; fin area (4 fins exposed), 136.5 sq in.; design weight (without propellant), 29.17 lb.

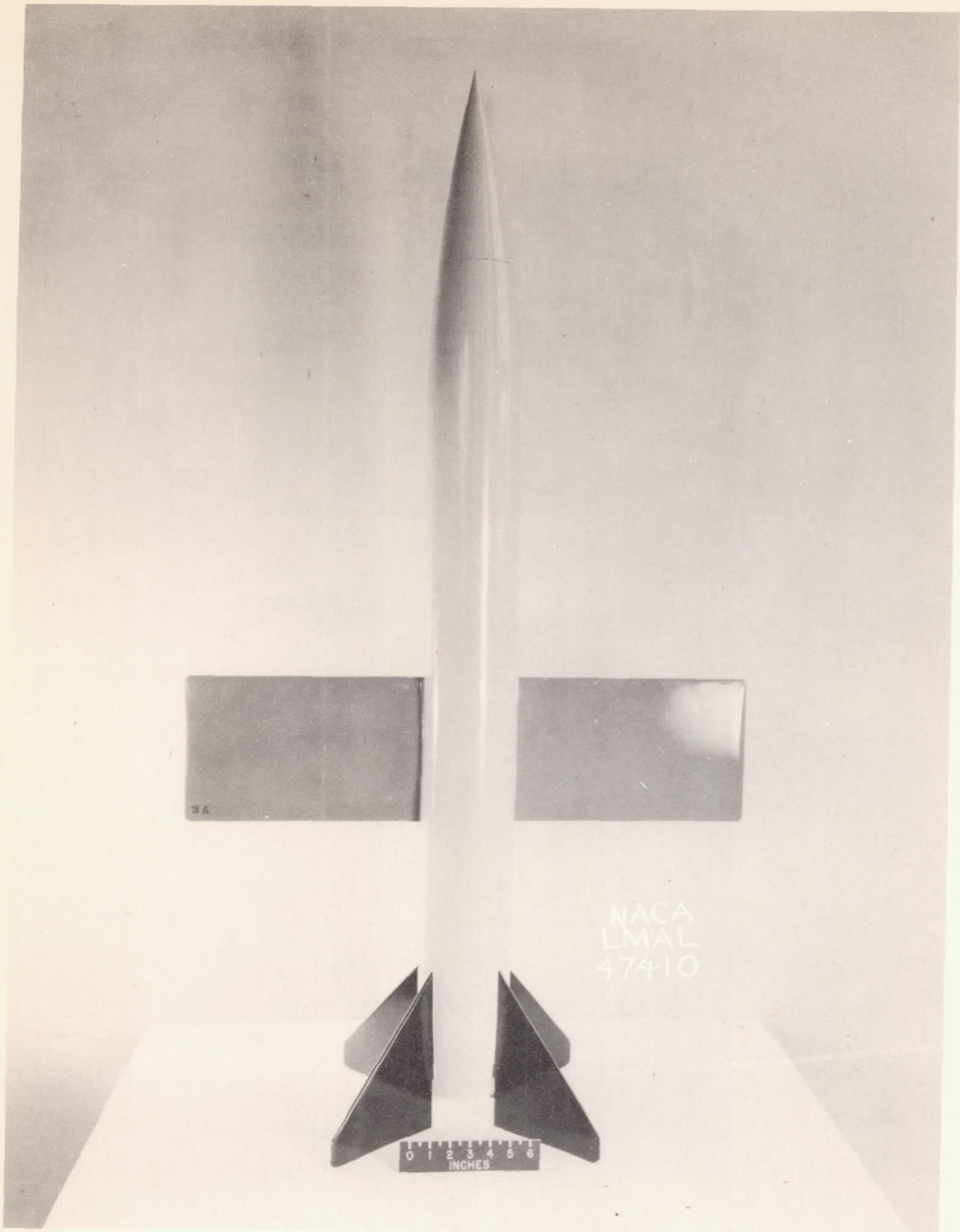


Figure 2.- The test body with unswept wing of aspect ratio 3.8.

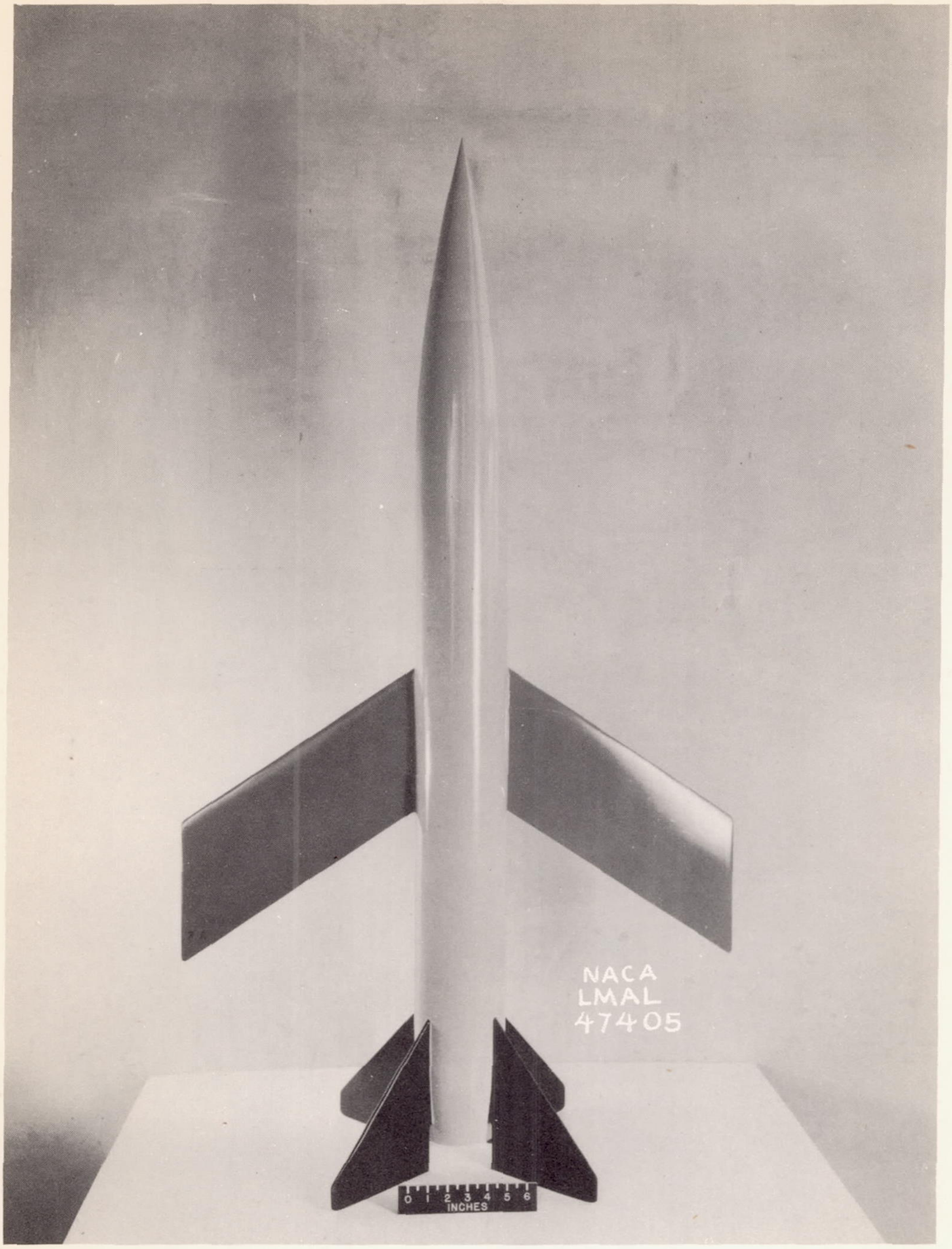


Figure 3.- The test body with 34° sweptback wing of aspect ratio 3.8.

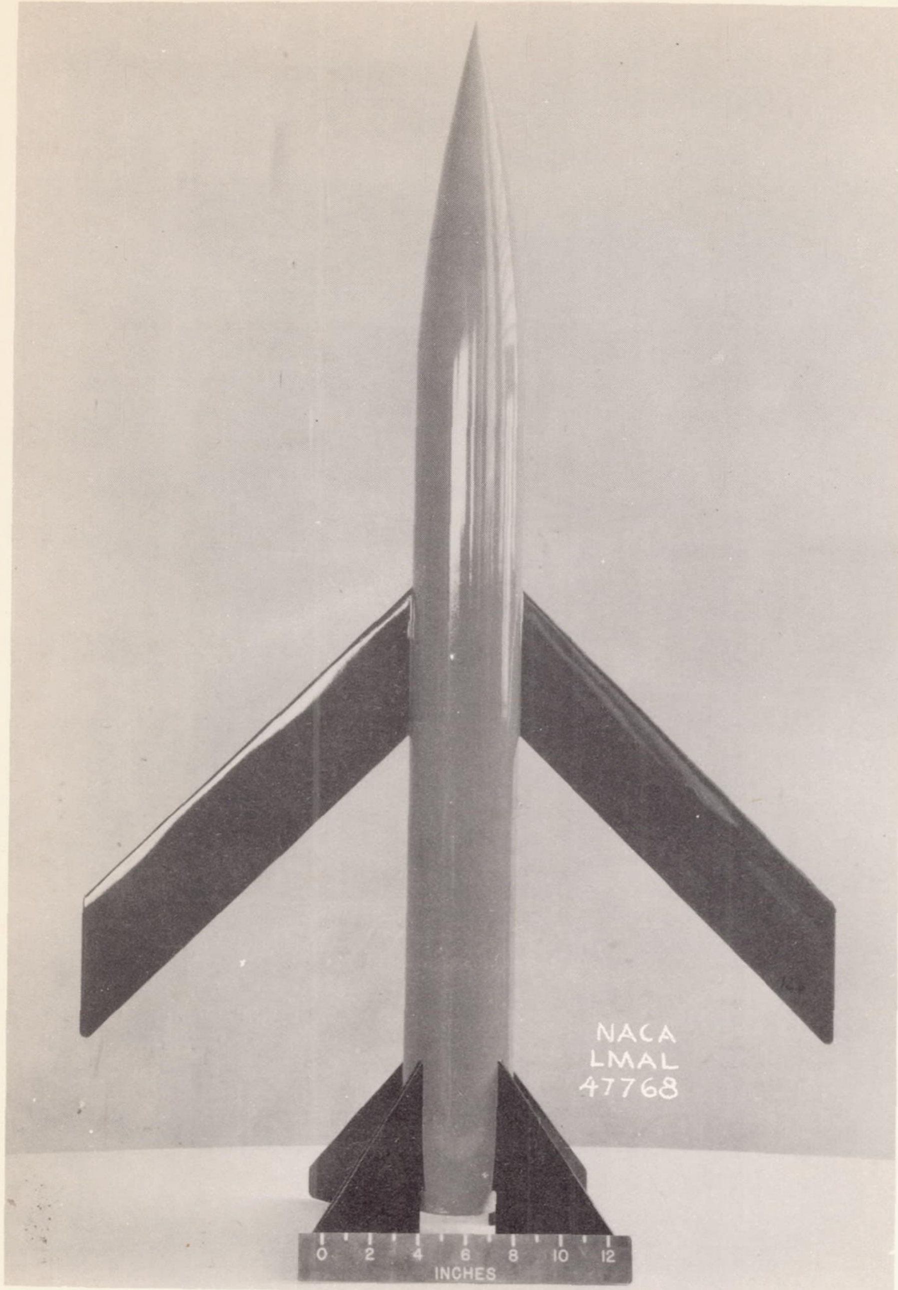


Figure 4.- The test body with 45° sweptback wing of aspect ratio 5.0.

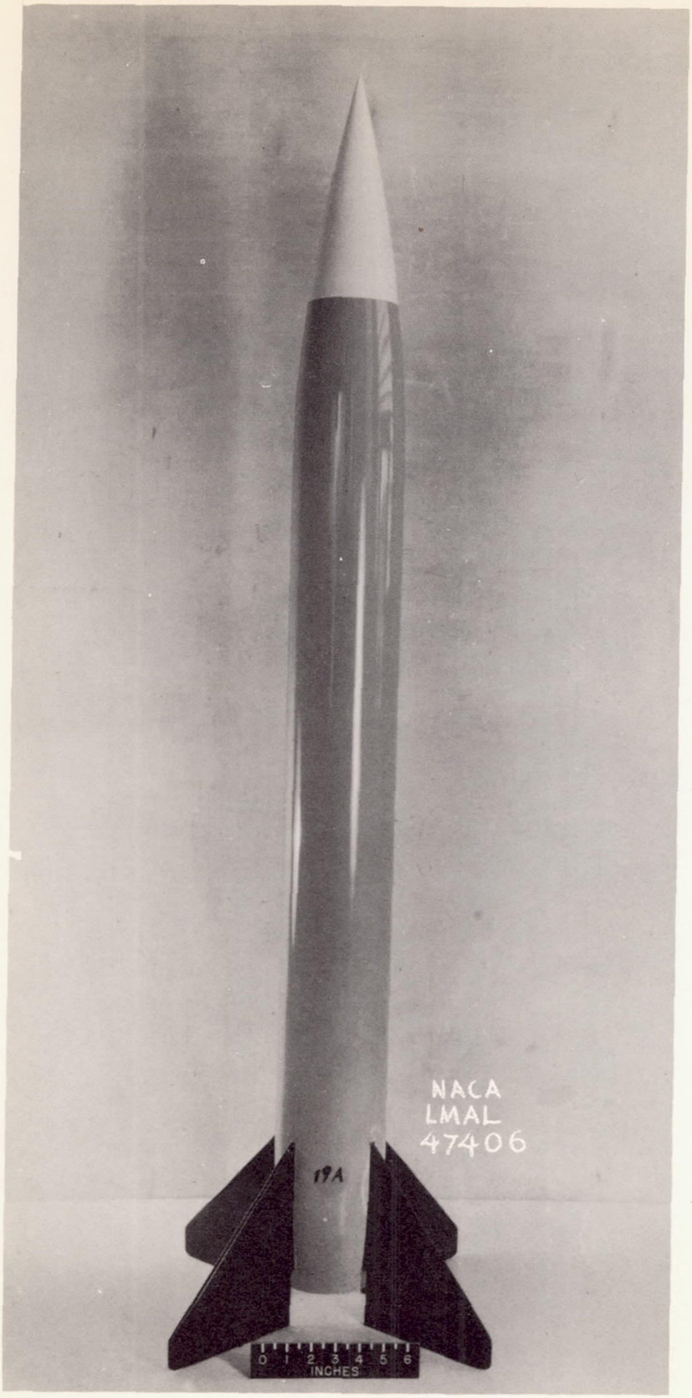


Figure 5.- The wingless test body of reference 1.

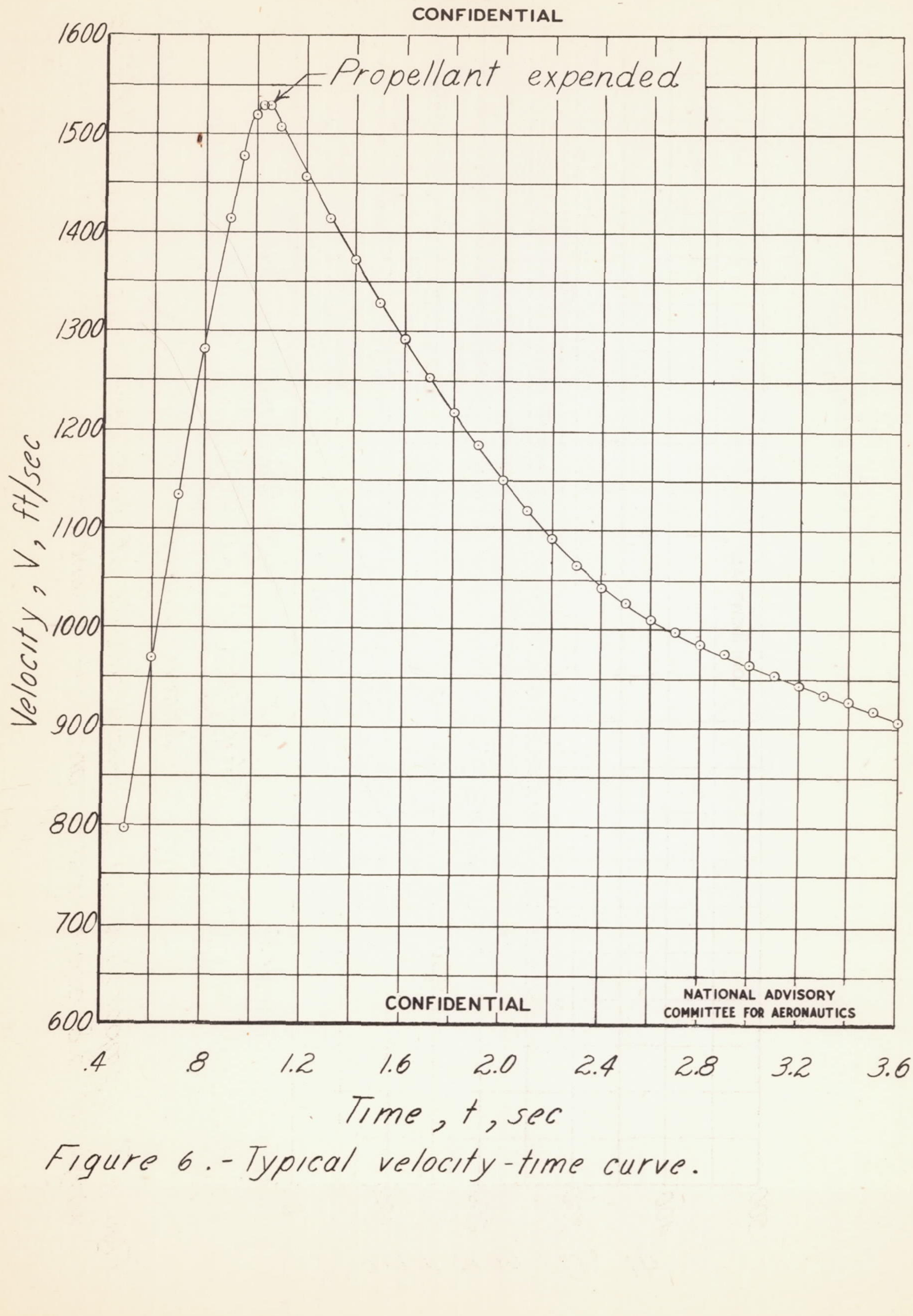


Figure 6.- Typical velocity-time curve.

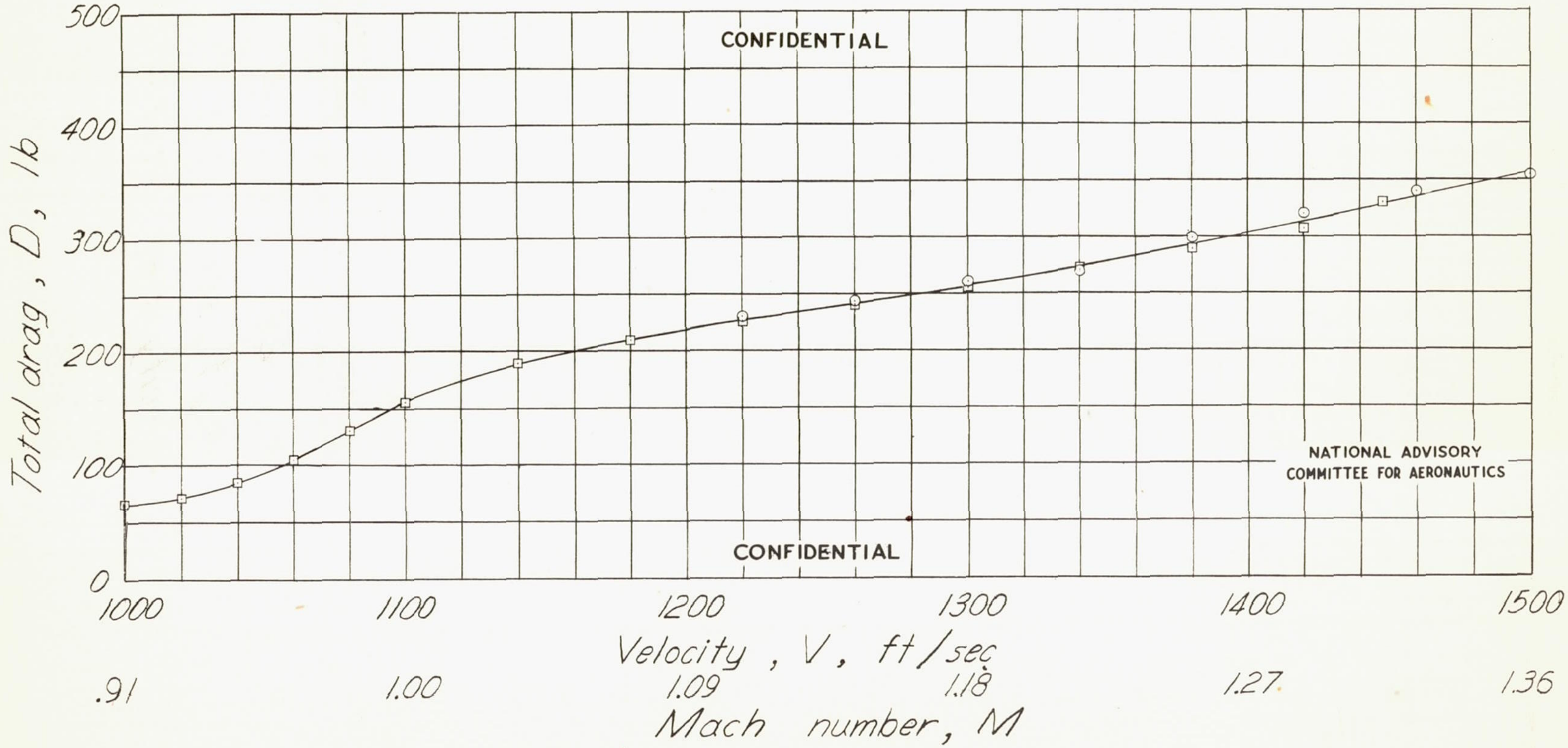
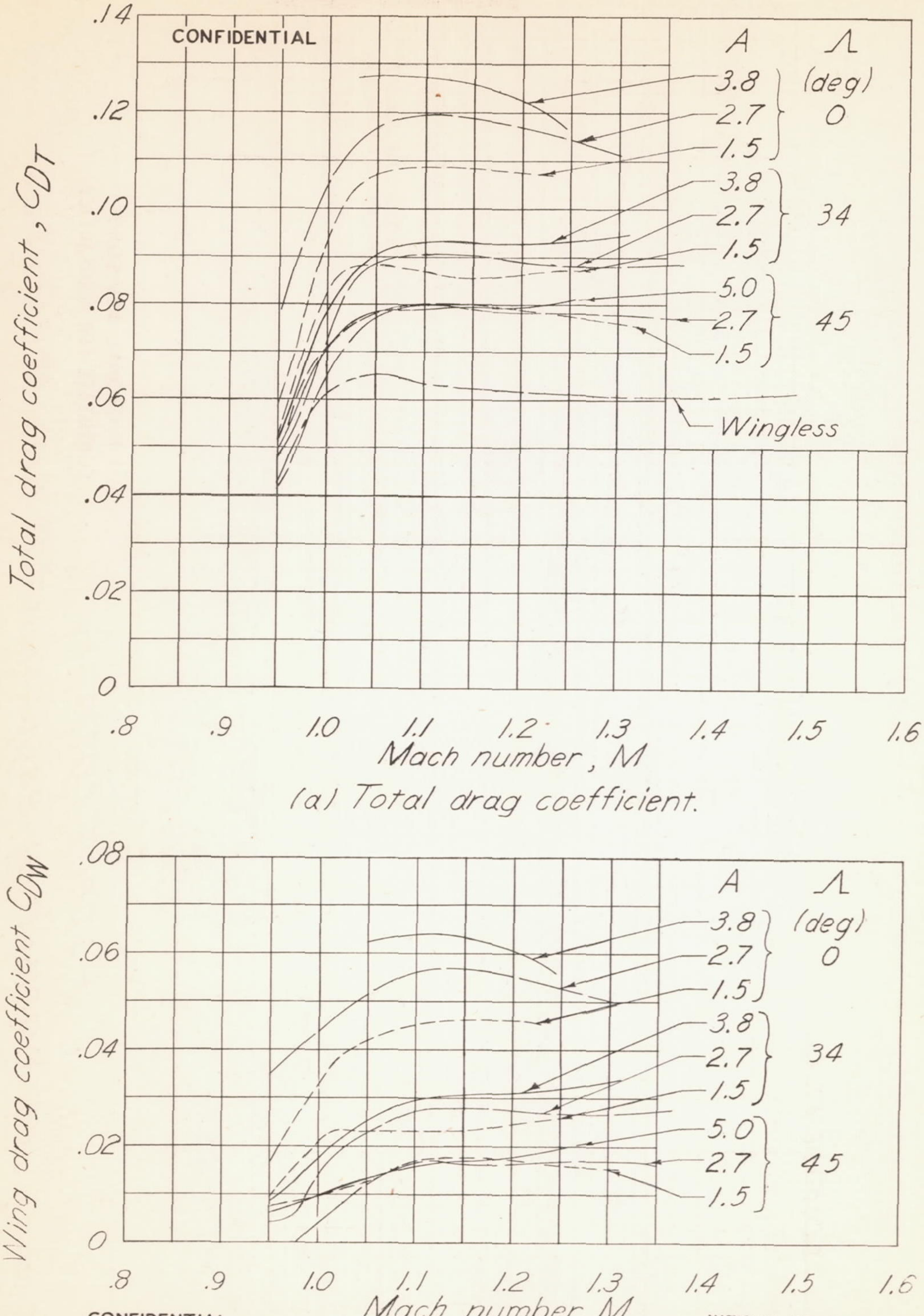


Figure 7.- Comparative drag measurements of two identical test bodies having wings of 3.8 aspect ratio and 34° sweepback



(a) Total drag coefficient.

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

(b) Wing drag coefficient.

Figure 8.- Effect of sweepback angle and aspect ratio on total drag coefficient and wing drag coefficient.

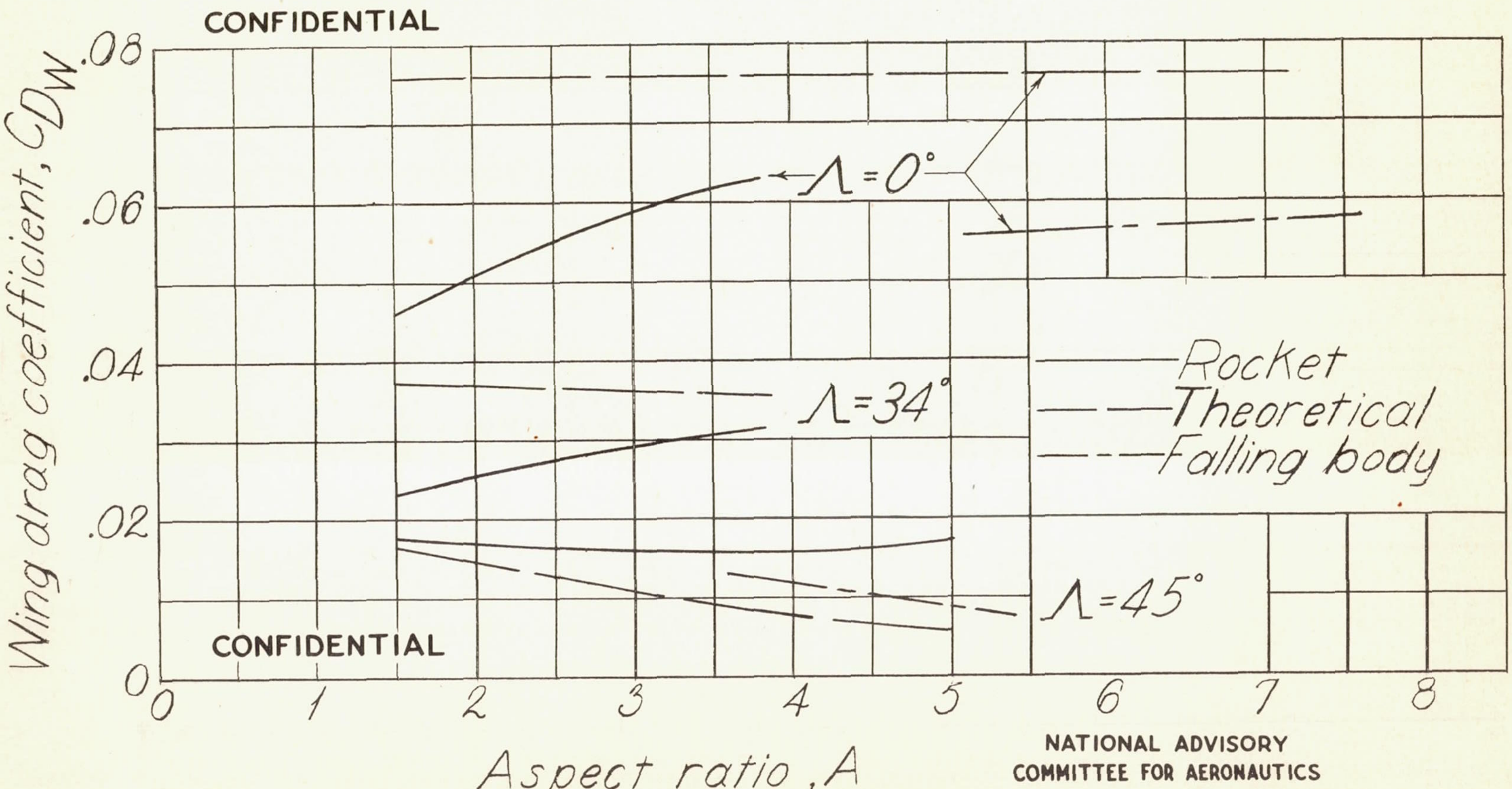


Figure 9 .- Comparison of experimental and theoretical variation of wing drag coefficient with aspect ratio. $M = 1.15$